

The effect of compensating filter on image quality in lateral projection of thoraco lumbar radiography

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Abstract. The aim of this project was to study the effect of compensating filter on image quality in lateral projection of thoraco lumbar radiography. The specific objectives of this study were to verify the relationship between density, contrast and noise of lateral thoraco lumbar radiography using various thickness of compensating filter and to determine the appropriate filter thickness with the thoraco lumbar density. The study was performed by an X-ray unit exposed to the body phantom where different thicknesses of aluminium were used as compensating filter. The radiographs were processed by CR reader and being imported to KPACS software to analyze the pixel depth value, contrast and noise. Result shows different thickness of aluminium compensating filter improved the image quality of lateral projection thoraco lumbar radiography. The compensating filter of 8.2 mm was considered as the optimal filter to compensate the thoraco lumbar junction (T12-L1), 1 mm to compensate lumbar region and 5.9 mm to compensate thorax region. The addition of aluminium compensating filter is advantageous in terms of efficiency which saving radiograph film, workload of the radiographer and radiation dose to patient.

1. Introduction

Imaging body parts such as lateral thoraco lumbar radiography is a challenge due to different composition and density of thorax and lumbar area. The difference may cause non uniformity of optical density on radiograph. There are several techniques to overcome the limitation in lateral thoraco lumbar radiography such as using a high tube voltage technique, two exposure techniques and the use of compensating filter.

One advantage of using high kV technique is shorter exposure time [1]. The higher the energy, the more photons will penetrate the body, the less that are absorbed. Although this reduces patient dose, image quality is compromised due to reduced contrast of a preferentially forward scattered radiation [2], [3]. Another technique can be used to overcome this issue is known as two exposure technique where the images may be taken twice with different exposure parameters. It produces two images in two exposures; one is thoracic and the other is lumbar. However it has disadvantage of doubling the dose to the patient since the exposure is taken twice. Additionally, it increases the time and workload of the radiographer.

Filters are important for the purpose of patient protection and improving radiographic image quality [4]. It is used in medical imaging to attenuate and hardened the x-ray beam spectrum [5]. Increasing the thickness of the filter removes a great number of low energy photons that is absorbed in



the body, thus reducing the radiation dose to patient [6]. The usage of compensating filter is effective as it is designed specifically for anatomical area that consist of varying thickness and density [7]. One advantage of compensating filter is anatomy of significant varying thickness can be imaged with a single exposure. Other advantages are quick and ease of use [8]. In this study, aluminium was used as compensating filter as it reduces the proportion of low energy photons which is absorbed in the body. It is used due to its low atomic number thus a suitable filter material for the purpose of tissue compensation [9].

The research on the use of compensating filter in radiography has been conducted by several authors [10], [11]. A special aluminium wedge filter has been used in scoliosis radiography. The thickness of the filter is 19 mm in the chest region and 6.5 mm in the abdomen region [10]. Wieder and Adam use the trough filter made of aluminium for posteroanterior chest radiographs. It consists of a square plate of aluminium with a centre trough that helps to produce high quality chest radiograph [11].

In image quality, radiographic density is the measure of overall darkening of the image. Density is a logarithmic unit that describes the ratio between light incident on the film and light being transmitted through the film [12]. The higher the radiographic density shows the more opaque areas of the film. The lower the density represents more transparent areas of the film. In term of pixel depth, the values varies from 0 (intensity for black pixel) to 255 (intensity for white pixel). In X-ray radiography, noise is the relevant comparison to contrast. In this study, noise properties of an image are described in terms of standard deviation measured within a region of interest (ROI) [13].

The main purpose of this research is to study the effect of compensating filter on image quality in lateral projection of thoraco lumbar radiography. The first specific objective of this study is to verify the relationship between density, contrast and noise of lateral thoraco lumbar radiography using various thickness of compensating filter. Besides, the study is conducted to determine the appropriate filter thickness with the thoraco lumbar density.

2. Material and method

2.1. Radiography

The experiment was conducted in X-ray laboratory of UiTM Puncak Alam. The study was performed using X-ray unit model Philips with equivalent filtration of 2 mm aluminium. The source to image distance (SID) was set to 100 cm.

2.2. Phantom

A Whole Body Phantom PBU-50 was placed in lateral projection. It is full body anthropomorphic phantom consists skeleton, lungs, liver, mediastinum and kidneys embedded in KYOTOKAGAKU original soft tissue. The movable joints allow the positioning of lateral projection of thoraco lumbar radiography.

2.3. Compensating filter

The compensating filter was constructed from a single piece of aluminium of 10 cm x 10 cm dimensions. The aluminium thickness ranged between 1 mm to 11 mm. The filter is placed in front of the light beam diaphragm with the aid of a filter holder. A number of images were acquired with different thicknesses of filter, ranging from 1 mm to 11 mm, in steps of 1 mm.

2.4. Exposure factor

A series of AEC exposure was made to determine the optimum kVp and mAs without the aluminium compensating filter. Another series of exposure then was made to determine the optimum kVp and mAs with the aluminium compensating filter. In this experiment the optimum kVp and mAs was 85 kVp and 20 mAs. The exposures parameters were kept constant throughout the experiment while the

compensating filter was inserted from least to the greatest so that the effect of increasing the thickness of aluminium compensating filter on image quality can be evaluated.

2.5. Image analysis

The images were processed and read by the REGIUS CR reader MODEL 210. The radiographs were imported to the KPACS software for the analysis purpose. The KPACS software was used to analyse the pixel value, contrast and noise of the images. The relationship between densities of thorax and lumbar with various thickness of compensating filter was verified. Besides, the appropriate filter thicknesses with thoraco lumbar density was determined.

Using (1) the Optical Density (OD) was calculated

$$\text{Optical Density (OD)} = 2 - \left[\frac{220 - \text{Pixel Depth Value}}{100} \right] \quad (1)$$

The additive factor for each region of thorax and lumbar were calculated by equation (2)

$$\text{Additive factor} = \frac{\text{Pixel Depth value for thickness } x}{\text{Pixel Depth value with zero thickness}} \quad x = 1\text{mm}, 2\text{mm} \dots 11\text{mm} \quad (2)$$

Thickness of Aluminium compensating filter required to compensate the thorax and lumbar region is the value which the ratio of optical density between thorax and lumbar equal to 1. It was calculated using equation (3)

$$\text{Appropriate filter thickness} = \frac{\text{OD Thorax}}{\text{OD Lumbar}} = 1 \quad (3)$$

3. Result and discussion

3.1. Pixel depth value analysis

The graph of pixel depth value versus thickness of aluminium filters for a step of T8, T9, T10, T11, T12 in thorax region and L1, L2 and L3 in the lumbar region was shown by the graph in Figure 1. As the filter thickness increased, the value of pixel slightly increased (density reduced). There was sudden change of pixel values between 5 to 6 mm of aluminium thickness due to the characteristics of x-ray. At this point, the compensation was effective as the filter compensate more than others.

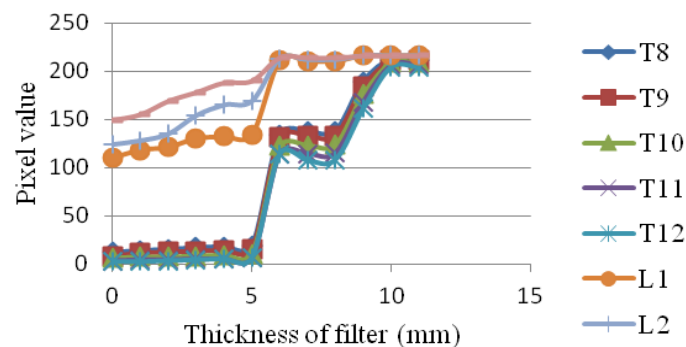


Figure 1. Graph of Pixel value vs Thickness of filter for different region of Thorax and Lumbar.

The compensating filter absorbs radiation according to the thickness of the filter. Without compensating filter, pixel depth value of lumbar L1-L3 is higher (low density) compared to the pixel depth value of thorax T8-T12 (high density) means that the thorax region was too dark (black) while the lumbar region shows the good quality image and acceptable in image diagnosis. More filter thickness is required to compensate the thorax region to decrease its density while maintaining the density of the lumbar region. However, increasing too much thickness of the filter improved the image of thorax but reduced the image quality of lumbar. Due to this reason we need to design one compensating filter with appropriate thickness in order to compensate both thorax and lumbar region so that the thoraco lumbar region can be imaged in one exposure.

3.2. Noise analysis

Figure 2 shows the graph of standard deviation in different regions when using different thicknesses of aluminium filter. The standard deviation represents the noise of an image. In relation to the contrast, noise increased as the contrast increased. The lower density difference means there is lower contrast. Contrast within a film increases with increasing density difference. In thorax region, the noise level slightly increased with increasing of filter thickness and recommended the maximum thickness is 6 mm. Thickness of 7 mm to 11 mm has reduced the image quality of the thorax region. In a lumbar region, noise decreased as the thickness of filter increased.

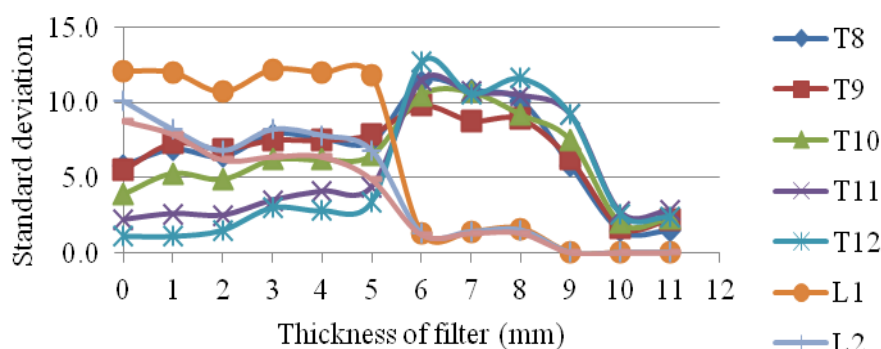


Figure 2. Graph of Standard deviation vs Aluminium Thickness for different region of Thorax and Lumbar.

3.3. Additive factor

In thorax region, the additive factor of pixel value was greater than 1 with the increasing of filter thickness. The density was highly reduced in the thorax region. The factor was approximately 1 for lumbar region since the density was almost high at lumbar region even there was no compensating filter involved.

Based on the additive factor calculation, the appropriate thickness of filter was 8 mm maximum in the thorax and 1 mm maximum in the lumbar region. Even though thickness of 6 mm, 7 mm and 8 mm contribute to the optimum density of thorax, thickness of 8 mm was preferable in term of dose in which it reduced more dose compared to the other two.

3.4. Design of wedge compensating filter

Figure 3 shows the graph of optical density vs thickness of filter in thorax and lumbar region respectively. In order to design the wedge compensating filter, the appropriate thickness of the filter was determined specifically for lumbar and thorax region by calculating equation (3).

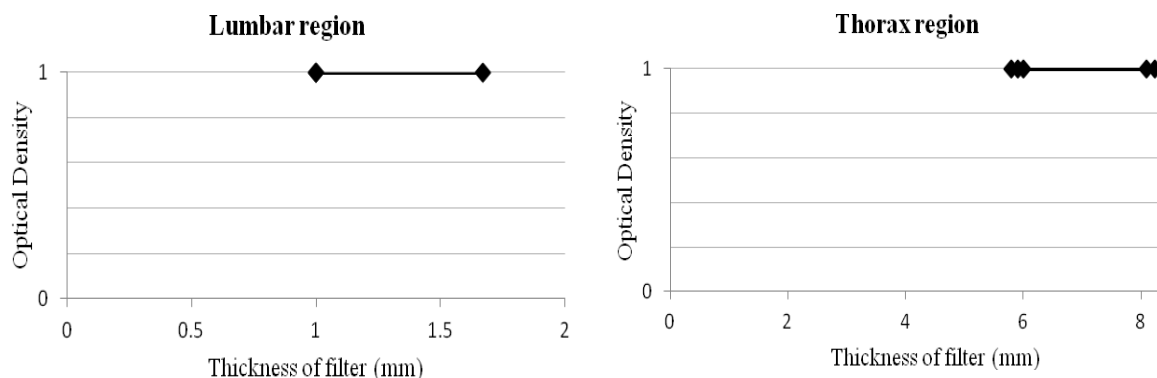
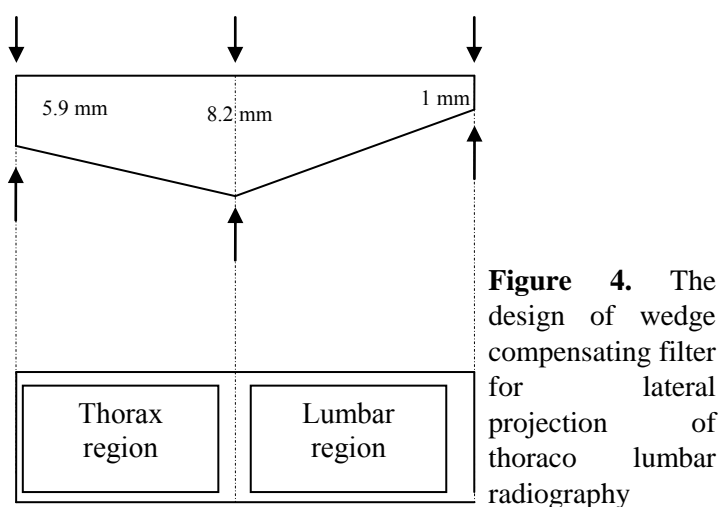


Figure 3. Graph of optical density vs thickness of aluminium filter in lumbar and thorax region

The shape of aluminum wedge compensating filter is shown in Figure 4. The wedge compensating filter was attached to the perspex holder and can be inserted into the x-ray collimator. The size of the filter was 10 cm x 10 cm. The minimum filter thickness was 1 mm in the lumbar region while 5.9 mm in the thorax region. The thickness increased towards the thoraco lumbar area contributes the maximum thickness of 8.2 mm in the region between thorax and lumbar region (thoraco lumbar junction) which is between T12-L1.



4. Conclusion

There are many advantages when using compensating filter for lateral projection of thoraco lumbar radiography. It was efficient in imaging the part of varying tissue thickness and density. It also improves the image quality of the radiography. The radiographer in this case has potentially saved the patient from being exposed to a large radiation because the design of compensating filter allows the single exposure instead of two. Therefore, saving the time and workload of the radiographer.

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